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on

INFLUENCE OF ALLOY PARTICLE SIZE AND SHAPE

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The influence of alloy particle size and shape in determining the behavior of dental amalgam was apparently not fully recognized in the earliest work since there is little mention of this subject in the available literature dating prior to 1918. Between 1918 and 1923, however, there were several papers published by A. W. Gray in which the author reported that alloy particle size has a significant effect upon the dimensional changes which occur during the hardening of dental amalgam[1-3]. He also showed that it is possible to control the dimensional change by a suitable blending of particle sizes.

Following Gray's paper there was a period of about twenty years during which the subject of particle size was virtually absent from the published literature. However, it appears that during this period some alloy manufacturers conducted their own proprietary researches which ultimately led them to adopt a more effective control over the particle size of their products. Coy and Liebig[4] showed that a finely-divided alloy had a much higher tensile strength after one day than did samples from a coarse-cut alloy but that after five days there was only a slight difference in tensile strength.

They emphasized the importance of particle size and shape in obtaining a dense structure with a minimum mercury content and one which would provide good adaptation to the cavity walls. They also indicated that the alloy particles are probably broken up during trituration. Thus the particle size in a freshly mixed amalgam is somewhat finer than the particle size of the alloy powder used in making it.

In 1942, Jarabak[5] presented the results of his studies on the effects of particle size, trituration and condensation pressure on the dimensional changes occurring in dental amalgam during hardening. An interesting review and discussion of particle size effects in dental amalgam was published by Smith[6] in 1949.

In all of these studies the particle size separations were accomplished by passing the alloy powders through sieves of various sizes. This procedure is not entirely satisfactory since the particles are usually in the form of elongated flakes or needles. Such particles may pass through the sieve in the direction of their longest axis and one thus obtains considerable variations in particle length for a given sieve size. Furthermore, it is possible that size fractions which are produced by sieving will not be greatly different in respect to their specific surface areas. For example, alloys passing

a coarse sieve may have significantly larger axial ratios than those passing a finer sieve. (The axial ratio being here defined as the length of the longest axis of a particle divided by the length of its shortest axis). The coarse particles with large axial ratios may then have a greater specific surface area than finer particles with an axial ratio closer to unity although on the basis of sieve size, one might have expected the opposite.

This problem was recognized by Crowell and Phillips[7] who attempted to separate the particles according to their thicknesses and then, by making certain simplifying assumptions, estimating the specific surface area corresponding to each thickness. The results indicated that increasing the specific surface area produces decreases in setting expansion, setting time and flow.

It produces an increase in the 1-hour and the 24-hour compressive strengths. Setting times were shown to be approximately a linear function of the reciprocal of the specific surface areas in agreement with a Noyes-Nernst equation. Setting expansion was directly related to surface area by a linear relationship.

With the appearance on the market of the so-called "fine-cut" alloys there was considerable discussion of the relative merits of the "fine-cut" versus "regular-cut" alloys. Mostellar has discussed this subject in relation to the ADA Specification #1 for dental amalgam[8]. The distinction between a fine-cut, regular-cut or coarse-cut alloy was difficult to establish on a quantitative basis, however, since there was a considerable variation in particle shape and size for a given type of alloy. Measurements of specific surface area for a given alloy were subject to much uncertainty and it was not feasible to measure the particle dimensions directly in order to reduce these uncertainties.

In a study of zinc and non-zinc alloys, Jendresen and Ryge[9] pointed out that although sieving separates large and small particles it does not produce a great difference in specific surface. By this time, therefore, it seems to have been recognized that the specific surface area of the particles was a parameter more directly related to the properties of the amalgam than "particle-size" as measured by sieving. It had become increasingly obvious that a method was needed for separating alloy particles on the basis of their specific areas rather than by sieve sizing .

The use of spherical alloy powders permits such a separation based on surface areas since the particle diameter of a sphere is directly related to its surface area. Furthermore, one may conveniently use the sieving method for separating the various sphere diameters since there is no longer any problem of elongated particles passing through the sieve in a preferred direction.

In 1961 Demaree and Taylor prepared a silver dental alloy having a typical composition and then had this alloy converted into spherical powders by a recently patented atomization process[10]. After separating the particles by sieving and by elutriation, they were able to show some remarkable correlations between the average particle size and such properties as setting change, flow and compressive strength[11]. There was also a relationship between average particle size and mercury content. In addition, they suggested that amalgams prepared from spherical particles would offer advantages from a clinical standpoint, such as a higher 1-hour compressive strength[11, 13] and less sensitivity to manipulative variables. Subsequent comparisons of amalgams prepared from spherical particles with those prepared from conventional lathe-cut

powders showed that the spherical-particle amalgams were as strong or stronger than conventional amalgams[12, 13], that they were stronger than conventional amalgams when both are subjected to low condensation pressures[12, 13], and that they exhibit superior adaptability in conforming to a cylindrical cavity[12]. In addition, data was obtained which established a quantitative relationship between average particle size and tensile strength. This showed that a maximum tensile strength is obtained at an average particle diameter of 15 to 25 microns[12]. The carvability and polish of the spherical-particle amalgams was also shown to depend on the particle size[13]. Clinical studies of spherical particle amalgams yielded favorable results and these amalgams are now used throughout the world.

In summary: quantitative relationships have been established linking the alloy particle size to tensile strength, compressive strength, flow, mercury content and dimensional changes during hardening. Indirectly, these parameters are also linked quantitatively with the specific surface area of the particles through the use of spherical particle amalgams. There are semi-quantitative or qualitative relationships linking alloy particle size to adaptability, carvability, plasticity, surface smoothness, polishability, and trituration time. Such

parameters as these, however, are difficult to define rigorously and it is even more difficult to obtain significant measurements. One must therefore rely heavily on clinical experience. In most cases, however, there is a sufficient knowledge of these variables to permit a reasonable estimate of clinical behavior.

The particle shape seems to be of some significance in determining the response of the amalgams to variations in packing pressure. The particle shape may also affect surface smoothness, carvability, adaptability and plasticity. Other properties may be affected indirectly due to a relationship between particle shape and the specific surface area of the particles.

The surface condition of the alloy particles is fairly important since surface films may be so thin as to be undetectable even by means of electron-diffraction techniques. They may nevertheless produce a significant change in the rate of hardening or the ultimate strength of the amalgam. The alloy particles may be given certain chemical treatments to remove surface films and further research may be needed in this area.

I would conclude, however, that at the present time our knowledge of the effects of particle size and shape upon the properties of dental amalgam is satisfactory. Some research

may be desirable in this area but it seems probable that this type of research can be best conducted by the manufacturers of these alloys who have access to proprietary information and who would be prompted by commercial motivations to provide the properties which are desired by the dentist. It seems unlikely that any major improvements will result from further study of the effects of particle size and shape. Future research might be more profitably directed toward understanding the basic reasons for the brittle fracture of the amalgams, their low tensile strengths as compared with their fairly high compressive strengths, and more details about the exact nature of the hardening reaction.

References

1. Gray, A. W. Metallographic Phenomena Observed in Amalgams, Trans AIME Suppl. to Bull. 144 Dec. (1918), also, J. Natl. Dent. Assoc. VI 513-531 (1919).

2. Gray, A. W. Contraction and Expansion of Amalgams with Time, Phys. Rev. 18, 108-113 (1921).

3. Gray, A. W. Volume Changes in Amalgams, J. Inst. Metals 29 139-189 (1923).

4. Coy, H. D. and Liebig, E. O. Dental Amalgam, Items of Int. Den. 60 135-147 (1938).

5. Jarabak, J. R. The Effect of Particle Size on Dimensional Change in Dental Amalgams, J.A.D.A. 29 593-605 (1942).

6. Smith, E. A. Particle Size of Dental Amalgam Alloys, British Dental Journal 86 34-36 (1949).

7. Crowell, W. S. and Phillips, R. W. Physical Properties of Amalgam as Influenced by Variation in Surface Area of the Alloy Particles, J. D. Res., 30 845-853 (1951).

8. Mosteller, J. H. An Evaluation of the A.D.A. Specification For Amalgam Alloy in Relation to Particle Size, Annals of Dentistry XII 19-24 (1953).

9. Jendresen, M. D. and Ryge, G. Effects of Particle Thickness of Zinc and Non-Zinc Alloys, Dental Progress 1 29/25, 33/29 (1960).

10. Probst, R. L., Karp, P. I., Sayre, C. H. and Beebe, A. H., Jr. assignors to Federal-Mogul-Bower Bearings Inc. Detroit, Michigan, Atomizing Nozzle and Pouring Cap Assembly for the Manufacturer of Metal Powders. U. S. Patent No. 2,968,062 Jan. 17, 1961.

11. Demaree, N. C. and Taylor, D. F. Properties of Dental Amalgams Made From Spherical Alloy Particles. J. D. Res., 41 890-906 (1962).

12. Eden, G. T. and Waterstrat, R. M. Effects of Packing Pressures on the Properties of Spherical Alloy Amalgams, J.A.D.A. 74 1024-1029 (1967).

13. Koran, A. and Asgar, K. A Comparison of Dental Amalgams Made From a Spherical Alloy and From a Comminuted Alloy. J.A.D.A. 75 912-917 (1967).